CLAIMS

1. A vehicle suspension system for a surface vehicle having a payload compartment and a surface engaging device, comprising:

a controllable suspension element for applying a force between said payload compartment and said surface engaging device;

a profile storage device for storing a plurality of profiles of paths,

said profiles including vertical deflection data; and

a profile retrieving microprocessor coupled to said controllable suspension element and to said profile storage device for retrieving from said profile storage device one of said profiles,

said one profile corresponding to the path on which said vehicle is traveling.

2. A vehicle suspension system in accordance with claim 1, wherein said profile storage device is located remotely from said surface vehicle.

3. A vehicle suspension system in accordance with claim 1, wherein said profile retrieving microprocessor is located remotely from said surface vehicle.

4. A vehicle suspension system in accordance with claim 1 and further comprising,

a locator system, coupled to said microprocessor for determining the location of said surface vehicle,

wherein said microprocessor is adapted to determine if there is stored in said profile storage device a profile corresponding to said location.

5. A vehicle suspension system in accordance with claim 1 and further comprising,

a sensor for acquiring vertical deflection data.

6. A vehicle suspension system in accordance with claim 5, wherein said microprocessor is adapted to compare said vertical deflection data with said stored profiles.

7. A vehicle suspension system in accordance with claim 5, wherein said microprocessor is adapted to modify said profile and to store said modified profile in said profile storage device.

8. A vehicle suspension system in accordance with claim 1 and further comprising,

a trajectory plan developing microprocessor for developing a trajectory plan corresponding to said retrieved profile.

9. A vehicle suspension system in accordance with claim 8 and further comprising,

a control processor for issuing command signals to said controllable suspension element to execute said trajectory plan.

10. An active vehicle suspension for a surface vehicle having a payload compartment and a surface engaging device, said vehicle for operating on a path, said suspension comprising:

a force applying element coupling said payload compartment and said surface engaging device for applying a force between said payload compartment and said surface engaging device to vary the vertical position of said payload compartment relative to said surface engaging device;

a profile storage device for storing a vertical profile of said path; and

a trajectory plan development subsystem communicatingly coupled to said force applying element and to said profile storage device for developing a trajectory plan responsive to said stored vertical profile and for issuing command signals to said force applying element,

said command signals corresponding to said trajectory plan.

11. An active vehicle suspension in accordance with claim 10, wherein said profile storage device is located remotely from said surface vehicle.

12. An active vehicle suspension in accordance with claim 10, wherein said trajectory plan development subsystem is located remotely from said surface vehicle.

13 A method for operating an active vehicle suspension system in a surface vehicle having a data storage device comprising:

determining the location of said surface vehicle;

determining if there is stored in said surface vehicle a vertical trajectory plan corresponding to said location;

retrieving said plan in response to a determination that there is stored in said vehicle suspension system said vertical trajectory plan, and

executing said plan.

14. A method for operating an active vehicle suspension in accordance with claim 13 and further comprising,

recording input signals from performance sensors;

modifying said vertical trajectory plan in response to the performance sensor input signals.

15. A method for operating an active suspension in accordance with claim 13, wherein said determining includes the use of a global positioning satellite.

16. A method for operating an active vehicle suspension in a surface vehicle having a sensing device to sense the vertical profile of a path and a data storage device comprising:

sensing a vertical profile of a path ;

recording said profile; and

comparing said recorded profile with profiles stored in a database to find if said sensed profile matches one of said stored profiles.

17. A method for operating an active vehicle suspension in accordance with claim 16 and further comprising,

retrieving, responsive to a finding that a sensed profile matches one of said stored profiles, a trajectory plan associated with said one stored profile; and

executing said trajectory plan.

18. A method for operating an active vehicle suspension in accordance with claim 17 and further comprising,

recording input signals from performance sensors;

modifying said vertical trajectory plan in response to the performance sensor input signals.

19. A method for operating an active vehicle suspension in accordance with claim 16 and further comprising,

responsive to a finding that said sensed profile matches one of said stored profiles, developing a trajectory plan for said sensed profile; and

executing said trajectory plan.

20. An active suspension system for a surface vehicle for operating on a path, comprising,

an active suspension;

a profile sensor for sensing a profile of said path;

road profile storage device for storing a database of path profiles; and

a path profile microprocessor coupled to said storage device and to said profile sensor for comparing said sensed profile with said database of path profiles.

21. An active suspension system in accordance with claim 20,

wherein said road profile storage device is located remotely from said surface vehicle.

22. An active suspension system in accordance with claim 20,

wherein said road profile microprocessor is located remotely from said surface vehicle.

23. An active suspension system in accordance with claim 20 and further comprising,

a trajectory plan storage device for storing a database of trajectory plans, said trajectory plans corresponding to said road profiles;

a trajectory plan microprocessor coupled to said storage device and to said road

profile microprocessor and responsive to said road profile microprocessor for retrieving one of said trajectory plans and for communicating instruction signals based on said one of said trajectories to said active suspension.

24. An active suspension system in accordance with claim 23, wherein said trajectory plan storage device is located remotely from said surface vehicle.

25. An active suspension system in accordance with claim 23, wherein said trajectory plan microprocessor is located remotely from said surface vehicle.

26. An active suspension system in accordance with claim 20 and further comprising,

a trajectory plan development microprocessor coupled to said active suspension for developing a vertical trajectory plan for said sensed profile.

27. An active suspension system for a surface vehicle comprising:

an active suspension;

a locator system for determining the location of said surface vehicle;

a trajectory plan storage device, for storing a database of trajectory plans corresponding to locations; and

a trajectory plan microprocessor for determining if said database contains a trajectory plan corresponding to said determined location, for retrieving said corresponding trajectory plan, and for transmitting to said active suspension instruction signals based on said corresponding trajectory plan.

28. An active suspension in accordance with claim 27, wherein said locator system comprises a global positioning system device.

29. A method for operating an active vehicle suspension system in a surface vehicle having a data storage device, comprising,

determining the location of said surface vehicle;

determining if there is stored in said surface vehicle a profile corresponding to said location;

retrieving said profile in response to a determination that there is stored in said vehicle suspension system said profile,

developing a trajectory plan in response to said retrieved profile, and

executing said trajectory plan.

30. A method for operating an active vehicle suspension in accordance with claim 29 and further comprising,

modifying said profile; and

storing said modified profile in said storage device.

31. A method for determining the location of a surface vehicle comprising:

storing a plurality of profiles of paths,

said path profiles associated with locations and containing only vertical deflections of said path from a predetermined reference plane measured at increments;

sensing vertical deflection of a path on which said vehicle is currently traveling from the predetermined reference plane; and

comparing said sensed vertical deflections with said path profiles.

32. For use with a vehicle including a suspension system, said vehicle suspension system comprising a trajectory planning system for developing a trajectory plan, a controllable suspension element for urging a point on said vehicle to follow said trajectory plan, a method for said developing of said trajectory plan, comprising:

recording a profile comprising data points, said data points representing positive and negative vertical deflections of a travel path;

smoothing data of said profile, said smoothing providing positive and negative values; and

recording said smoothed data as said trajectory plan.

33. An active vehicle suspension for a surface vehicle including a payload compartment and a surface engaging device, said vehicle for operating on a path, said path being characterized by a profile, said suspension comprising:

a force applying element coupling said payload compartment and said surface engaging device for applying a force between said payload compartment and said surface engaging device to modify the vertical position of said payload compartment relative to said surface engaging device;

a trajectory developing system communicatingly coupled to said force applying element, said trajectory developing system for developing a pre-determined path in space and for issuing command signals causing said force applying element to urge a point on said payload compartment to follow said pre-determined path in space.

34. An active vehicle suspension in accordance with claim 33, wherein said profile is expressed as one of force, velocity, and acceleration.

35. An active vehicle suspension in accordance with claim 33, said trajectory developing system comprising a device for smoothing said profile data to develop said pre-determined path in space.

36. An active vehicle suspension in accordance with claim 35, wherein said smoothing device comprises a low-pass filter.

37. An active vehicle suspension in accordance with claim 36, wherein said smoothing device comprises a bi-directional low pass filter.

38. A method for developing a trajectory plan for use with an active vehicle suspension, comprising:

operating said vehicle on a section of road;

recording data points representative of a profile of said section of road; and

smoothing said data to provide said trajectory plan, said smoothing preserving positive and negative values of said data points.

39. A method for developing a trajectory plan in accordance with claim 38, wherein said smoothing comprises a low pass filtering of said data points.

40. A method for developing a trajectory plan in accordance with claim 39, wherein said low pass filtering comprises a bi-directional low pass filtering of said data points.

41. A method for developing a trajectory plan in accordance with claim 40, further comprising a second bi-directional low pass filtering of said data.

42. A method for developing a trajectory plan in accordance with claim 38, wherein said data points represent said vertical deflections measured with respect to time.

43. A method for developing a trajectory plan in accordance with claim 38, wherein said profile data points represent vertical deflections measured with respect to distance traveled.

44. A method for operating a vehicle, said vehicle including a controllable suspension element, a microprocessor, and sensors for measuring at least one of vertical deflection, force applied by said controllable suspension, vertical velocity, and vertical acceleration, said method comprising:

storing a library of a plurality of profiles;

driving said vehicle over a road section and recording data measured by said sensors to provide measured data; and

comparing said measured data with said plurality of profiles to determine a degree of match.

45. A method for operating a vehicle in accordance with claim 44, said storing comprising storing said library of profiles as one of acceleration, velocity, and force.

46. A method for operating a vehicle in accordance with claim 44, further comprising:

if said comparing indicates a high degree of match, determining if there exists a trajectory plan corresponding to said measured data; and

if said determining indicates that a trajectory plan exists, retrieving and executing said trajectory plan.

47. A method for operating a vehicle in accordance with claim 46, further comprising:

if said determining indicates that a trajectory plan does not exist, creating a trajectory plan using said measured data.

48. A method for operating a vehicle in accordance with claim 44, further comprising:

if said comparing does not indicate a high degree of match, storing said measured data as a profile in said library of profiles.

49. A method for operating a vehicle in accordance with claim 48, further comprising creating a trajectory plan corresponding to said measured data.

50. A method for operating a vehicle in accordance with claim 44 further comprising the step of, if said comparing does not indicate a high degree of match, calculating a trajectory plan corresponding to said measured data.

51. A method for operating a vehicle in accordance with claim 44, wherein said stored data include states of said vehicle measured by said sensors, said data expressed as at least one of vertical deflection, force, acceleration and velocity.

52. A method for developing an optimized trajectory plan for a vehicle including a controllable suspension element, comprising:

a first developing, by a microprocessor, using a first characteristic value, of a first trajectory plan corresponding to a profile;

a first executing, of said first trajectory plan, said first executing including recording performance data corresponding to said first trajectory plan;

a first modifying, of said first characteristic value to provide a second characteristic value;

a second developing, using said second characteristic value, by said microprocessor, of a second trajectory plan corresponding to said profile;

a second executing, of said second trajectory plan, said second executing including recording a measure of performance data corresponding to said second trajectory plan;

a first comparing of said performance data corresponding to said executing of said first trajectory plan and said performance data corresponding to said executing of said second trajectory plan to determine better performance data; and

a first storing, as a current characteristic value, of a one of said first characteristic value and said second characteristic value corresponding to said better performance data.

53. A method for developing an optimized trajectory plan in accordance with claim 52, wherein said executing of at least one of said first trajectory plan and said second trajectory plan is a simulated executing, by said microprocessor, of said at least one of said first trajectory plan and said second trajectory plan.

54. A method for developing an optimized trajectory plan in accordance with claim 52, further comprising a second storing, of a one of said first trajectory plan and said second trajectory plan corresponding to said better performance data, as a current trajectory plan.

55. A method for developing an optimized trajectory plan in accordance with claim 54, further comprising:

subsequent to said first executing, and prior to said first modifying, comparing said performance data with a pre-determined threshold performance value.

56. A method for developing an optimized trajectory plan in accordance with claim 55 further comprising, in the event that said performance data is at least said pre-determined threshold performance, omitting said first modifying, said second developing, said second executing, and said comparing, and wherein said storing comprises storing said first characteristic value as said current characteristic value.

57. A method for developing an optimized trajectory plan in accordance with claim 55, further comprising, in the event that said performance data is less than said pre-determined threshold performance,

a second modifying, of said current characteristic value to provide a third characteristic value;

a third developing, using said third characteristic value, by said microprocessor, of a third trajectory plan corresponding to said profile;

a third executing, of said third trajectory plan, said third executing including recording a measure of performance data corresponding to said third trajectory plan, wherein said measure of performance data is one of an actual measured performance and a calculated measure of performance calculated from said simulated executing of said third trajectory plan;

a second comparing of said performance data corresponding to said executing of said current trajectory plan and said performance data corresponding to said executing of said third trajectory plan to determine better performance data;

a third storing, as a new current characteristic value, of a one of said current characteristic value and said third characteristic value corresponding to said better performance data; and

a fourth storing, as a new current trajectory plan, of a one of said current trajectory plan and said third trajectory plan.

58. A method for developing an optimized trajectory plan in accordance with claim 54, further comprising:

a second modifying, of said current characteristic value to provide a third characteristic value;

a third developing, using said third characteristic value, by said microprocessor, of a third trajectory plan corresponding to said profile;

a third executing, of said third trajectory plan, said third executing including recording a measure of performance data corresponding to said third trajectory plan, wherein said measure of performance data is one of an actual measured performance and a calculated measure of performance calculated from said simulated executing of said third trajectory plan;

a second comparing of said performance data corresponding to said executing of said current trajectory plan and said performance data corresponding to said executing of said third trajectory plan to determine better performance data;

a third storing, as a new current characteristic value, of a one of said current characteristic value and said third characteristic value corresponding to said better performance data; and

a fourth storing, as a new current trajectory plan, of a one of said current trajectory plan and said third trajectory plan.

59. A method for developing an optimized trajectory plan in accordance with claim 52, further comprising:

subsequent to said executing of said first trajectory plan, comparing said performance data with a pre-determined threshold performance value.

60. A method for developing an optimized trajectory plan in accordance with claim 59 further comprising in the event that said performance data is at least said pre-determined threshold performance, omitting said modifying, said second developing, said second executing, and said comparing.

61. A method for developing an optimized trajectory plan in accordance with claim 59, further comprising in the event that said performance data is less than said pre-determined threshold performance,

a second modifying, of said current characteristic value to provide a third characteristic value;

a third developing, using said third characteristic value, by said microprocessor, of a third trajectory plan corresponding to said profile;

a third executing, of said third trajectory plan, said third executing including recording a measure of performance data corresponding to said third trajectory plan, wherein said measure of performance data is one of an actual measured performance and a calculated measure of performance calculated from said simulated executing of said third trajectory plan;

a second comparing of said performance data corresponding to said executing of said current trajectory plan and said performance data corresponding to said executing of said third trajectory plan to determine better performance data; and

a second storing, as a new current characteristic value, of a one of said current characteristic value and said third characteristic value corresponding to said better performance data.

62. A method for developing a trajectory plan in accordance with claim 52, wherein said microprocessor is in a computer remote from said vehicle and further including the steps of:

downloading said trajectory plan from said computer to said vehicle.

63. A method for developing a trajectory plan in accordance with claim 52, wherein said microprocessor is on-board said vehicle.

64. A method for developing a trajectory plan in accordance with claim 52, wherein said at least one of said characteristic values is a filter break frequency.

65. A method for developing a trajectory plan for use by a vehicle including a payload compartment, a wheel, a plurality of sensors for measuring a corresponding plurality of states of said vehicle, and a controllable suspension element for exerting force between said wheel and said payload compartment, comprising:

storing said trajectory plan as one of

a series of commands causing said controllable suspension element to exert a force, and

a series of states of said vehicle as measured by at least one of said sensors.

66. A method for developing a trajectory plan for use by a vehicle including a payload compartment, a wheel, a plurality of sensors for measuring a corresponding plurality of states of said vehicle, and a controllable suspension element for exerting force between said wheel and said payload compartment, comprising:

recording a profile comprising data points measured by said sensors, said data points representing positive and negative vertical values;

storing said profile as one of

a series of commands causing said controllable suspension element to exert a force, and

a series of states of said vehicle as measured by at least one of said sensors.

67. An active vehicle suspension for a surface vehicle including a payload compartment and a surface engaging device, said vehicle for operating along a path, said suspension comprising:

a controllable suspension element for modifying the displacement between said payload compartment and said surface engaging device responsive to vertical displacements in said path; and

a trajectory developing subsystem for issuing commands to said controllable suspension element causing said controllable suspension element to exert a force to modify the displacement between said payload compartment and said surface engaging device prior to said surface engaging device encountering said vertical displacement.

68. A method for operating a vehicle on a road segment including vertical disturbances, said vehicle comprising payload compartment, a controllable suspension element and sensors, associated with said controllable suspension element, for sensing at least one of vertical acceleration, vertical velocity, and vertical displacement, said method comprising:

providing data representative of a one said vertical disturbances; and

issuing a command to said controllable vehicle suspension to exert a force related to said one vertical disturbance before said road engaging device encounters said vertical disturbance.

69. A method for operating a vehicle in accordance with claim 68, wherein said providing comprises:

driving said vehicle over said road segment; and

recording data from said sensors.

70. A method for operating a vehicle in accordance with claim 69, further comprising smoothing the data to provide a trajectory plan, and wherein said issuing includes issuing commands that cause said controllable suspension to cause said payload to follow said trajectory plan.

71. A method for operating a vehicle in accordance with claim 68, wherein said providing comprises retrieving a profile from a library of profiles.

72. A method for operating a vehicle including a payload compartment and a front surface engaging device and a rear surface engaging device, said vehicle further including a suspension system, said suspension system including a front controllable suspension element for exerting a force between said front surface engaging device and said payload compartment to modify the distance between said front surface engaging device and said payload compartment, said front controllable suspension element having a centered position, said front controllable suspension element including a centering subsystem for urging said front controllable suspension element toward said centered position, said suspension system further including a rear controllable suspension element for exerting a force between said rear surface engaging device and said payload compartment to modify the distance between said rear surface engaging device and said payload compartment, said rear controllable suspension element having a centered position, said rear controllable suspension element including a controllable centering subsystem for urging said rear controllable suspension element toward said centered position, said method including:

operating said vehicle on a road segment including disturbances so that said front surface engaging device encounters said disturbances before said rear surface engaging device and so that said front controllable suspension element exerts forces responsive to said disturbances;

determining the amplitude of one of said road disturbances,

responsive to a determining that said amplitude of said one of said disturbances is less than a first threshold amount, disabling said rear suspension element centering subsystem.

73. A method for operating a vehicle in accordance with claim 72, further comprising:

responsive to a determining that said amplitude of said one of said disturbances is greater than said second threshold amount, causing said controllable suspension to exert a

force related to said one of said disturbances before said surface engaging device encounters said disturbance.

74. A surface vehicle comprising:

a payload compartment;

a front surface engaging device;

a rear surface engaging device; and

a suspension system including

a front controllable suspension element for exerting a force between said front surface engaging device and said payload compartment to modify the distance between said front surface engaging device and said payload compartment, said front controllable suspension element having a centered position, said front controllable suspension element including a centering subsystem for urging said front controllable suspension element toward said centered position, said front controllable suspension element further comprising a measuring system to measure the amplitude of a road disturbance encountered by said front surface engaging device; and

a rear controllable suspension element for exerting a force between said rear surface engaging device and said payload compartment to modify the distance between said rear surface engaging device and said payload compartment, said rear controllable suspension element having a centered position, said rear controllable suspension element including a controllable centering subsystem for urging said rear controllable suspension element toward said centered position; and

controlling circuitry, responsive to said measuring system, for disabling said rear suspension element centering subsystem.

75. A method for operating a vehicle including a payload compartment and a first surface engaging device and a second surface engaging device, said vehicle further including a suspension system, said suspension system including a first controllable suspension element for exerting a force between said first surface engaging device and said payload compartment to modify the distance between said first surface engaging device and said payload compartment, said suspension system further including a second controllable suspension element for exerting a force between said second surface

engaging device and said payload compartment to modify the distance between said second surface engaging device and said payload compartment, each of said first controllable suspension element and said second suspension element comprising associated sensors to measure at least one of vertical acceleration, vertical velocity, vertical road deflection, suspension displacement, and force applied by said controllable suspension, said method comprising:

operating said vehicle on a road segment having disturbances so that said first surface engaging device encounters said disturbances before said second surface engaging device;

measuring, by said sensors associated with said first controllable suspension element, said disturbances; and

based on said measuring, causing said second controllable suspension element to exert a force related to said disturbance before said second surface engaging device encounters said disturbance.

76. A method for operating a vehicle in accordance with claim 75, further comprising, based on said measuring, developing a profile of said road segment.

77. A method for operating a vehicle in accordance with claim 76, further comprising developing a trajectory plan for execution by said second controllable suspension element.

78. A method for operating a vehicle including a payload compartment and a surface engaging device said vehicle further including a suspension system, said suspension system including a controllable suspension element for exerting a force between a surface engaging device and said payload compartment to modify the distance between said surface engaging device and said payload compartment, said surface controllable suspension element having a centered position, said controllable suspension element including a reactionary operating mode and a trajectory plan operating mode, said method comprising:

driving said vehicle on a road segment having vertical disturbances;

determining the amplitude of said disturbances;

responsive to a determining that an amplitude of a one of said disturbances is less than a

first threshold amount, operating said controllable suspension element in said reactionary mode;

responsive to a determining that said amplitude of said one of said disturbances is greater than said first threshold amount and less than a second threshold amount, disabling said centering system; and

responsive to a determining that said amplitude of said one of said disturbances is greater than said second threshold amount, causing said controllable suspension to exert a force related to said one of said disturbances before said surface engaging device encounters said disturbance.